# A Flood Chronology for Cork City and its Climatological Background

**John G. Tyrrell**
*Department of Geography, University College Cork*

and

**Kieran Hickey**
*Department of Geography, Coventry Polytechnic*

## ABSTRACT

A flood chronology for the city of Cork is presented for the period 1841-1988. The 292 floods which are reported are classified into six flood types primarily based on the relative role of rainfall and tidal conditions in each flood event. Changes over the 148 years in flood frequencies and flood types are outlined and assessed, primarily with respect to the significance of the atmospheric circulation patterns and wind direction, but also with reference to the occurrence of river discharge levels and tidal surges. The major cause of flooding is shown to be excessive rainfall, although high tides are also of considerable significance, especially those accompanied by storm surges.

*Key Index Words*: Floods, wind, rainfall, tides, Cork.

## Introduction

The city of Cork has grown as a response to the variety of perceived benefits offered by its present waterside site at the head of the Lee estuary. Despite the flood risk associated with such a location, other advantages of the site have rendered the hazard acceptable. The flood risk in Cork city arises not only from catchment runoff, which from early times washed over the islands and marshes of the lower Lee valley, but also from its location in the tidal reaches of the estuary. This has additionally subjected the city to tidal fluctuations and inundations. Cork's expansion from its original island site onto the surrounding marshes was largely completed by the mid 19th century - the start of the period upon which this study is based. Since then the flood risk has neither abated nor remained constant. The present study examines the flood chronology of the city since 1841, when the present outline of the city was established, to 1988. It then examines the role of climatic, riverine and tidal components of the natural event system to understand the variability of flood frequencies over these 148 years.

### *Previous Work*

Some attention has been given to the frequency and temporal characteristics of floods in Cork (Walsh,1928; Dillon,1954). Generally, such work covers a more limited time span and is less comprehensive than the present study. Walsh (1928), using data for 1884-1927 examined the role of rainfall intensity and duration in flood events, together with their return period. He demonstrated the significance of rainfall intensities and antecedent conditions for three of the most severe floods in Cork's history - 17 January 1789, 2 November 1853 and 16 November 1916. Dillon (1954) extended this work to 1948, his results incorporating the higher rainfall of those additional decades and demonstrating the role of cyclonic disturbances. However, there was no detailed examination of the flooding itself.

There are few published Irish flood chronologies. Among those available is an incomplete one for Mallow (O'Sullivan, 1985,1986,1988) covering the period

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1840-1988. There is also one for Belfast (Prior and Betts, 1974) which gives a complete chronology for 1906-1972. The latter study included a consideration of urban site factors as well as excessive rainfall and high tides.

## Data Sources

Chronological reconstructions of past climatic conditions present significant methodological problems. This study extends into the period before which hydrological data were available for the city; therefore, it depends upon historical source materials for reconstructing the record. Of the two kinds of data normally used for this type of study, proxy and documentary data, the former were not used because of their inability to indicate specific events. Of the numerous documentary sources available the most consistent for the whole period was a local newspaper, the *Cork Examiner*. In addition, other documentary sources were available, and although their detail could at times be considerable, such records were found to be most useful for checking the *Cork Examiner* data since they were much more fragmented in their coverage.

The *Cork Examiner* was published three times a week between 1841 and 1861, after which it became a daily publication (except for Sundays). There are two main methods of using a newspaper for developing a flood chronology. The first is to identify the likely flood dates from another source, usually rainfall data (Clements, 1982; Walsh, Hudson and Howells, 1983; O'Sullivan, 1985,1986,1988). However, when rainfall is a factor of variable importance in causing the flooding, and other factors are likely to play a major role, as in Cork, this approach is likely to be unsatisfactory. The alternative is a blanket coverage of newspaper editions (Brierly, 1964; Brazell, 1968; Prior and Betts, 1974; Rawling, 1989).

The coverage of flood events in the *Cork Examiner* was seen to have varied with the size of the newspaper issue and the severity of the flooding. However, even small floods within the city were reported on a regular basis. The newspaper's information on floods is of good quality because of the strong awareness of the flood problem in the city (and also because the newspaper office is located on one of the flood-prone streets !). The coverage was, however, poor during the Second World War when there were restrictions on reporting weather and weather events. The record is incomplete, therefore, between early 1941 and late 1945.

To examine the role of rainfall in flood events, rainfall data were required. Continuous rainfall data are available from two rainfall stations within the area: Roches Point (from 1870) and Cork Airport (from 1960). The data from two other meteorological stations: Clover Hill and University College, were not suitable as they lacked comparable detail. The Roches Point record provides precipitation data for 270 of the 292 floods in the chronology. Until 1960 rainfall data are available for 6 a.m., 12 noon and 6 p.m. Thereafter, hourly falls were recorded. For the purposes of this study, the nearest 24 hour period prior to the flood event, plus the previous 24 hour total were used. The latter allowed for a timelag when rainfall in the upper catchment of the Lee would discharge into the lower Lee.

To incorporate the tidal conditions into the analysis, tidal data were based upon the Horgan's Quay gauge, which was operational from 1930. Discharge data were obtained from the Electricity Supply Board's gauge at Leemount Lower Bridge, upstream from the city, from 1950. Storm surge data were derived by subtracting the predicted tide height from the actual recorded height at Horgan's Quay.

## The Flood Chronology

From 1841 to 1988 Cork city was affected by 292 floods (Figure 1). From the beginning of this period the frequency of floods have gradually increased. There was a particularly dramatic increase during the 1920s and 1930s, with the decade of most frequent flooding being the 1960s (Figure 2).

Nearly 60% of the floods occurred in the period November - February (Figure 3). Therefore, it seemed appropriate to examine annual frequencies using a July - June year. In all cases the year is referred to by the calendar year in which July occurs. The annual frequencies are shown in Figure 4 where a much greater variability is apparent than is shown by the decadal pattern. Between 1925 and 1939 there were 77 floods, over a quarter of the total for the entire research period. In fact, this peak period may be more extensive since the information for the first five years of the 1940s is not available. The three exceptional years of

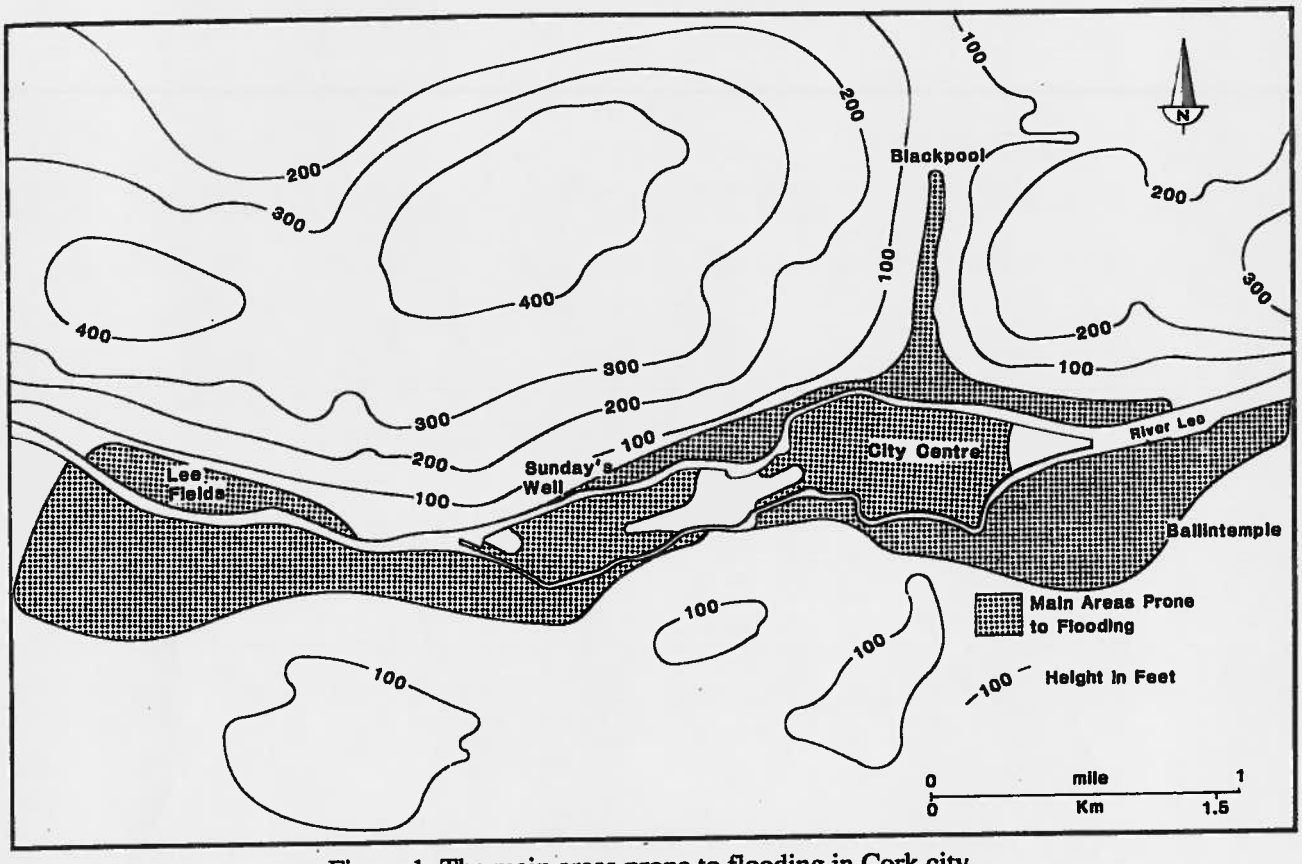


Figure 1: The main areas prone to flooding in Cork city

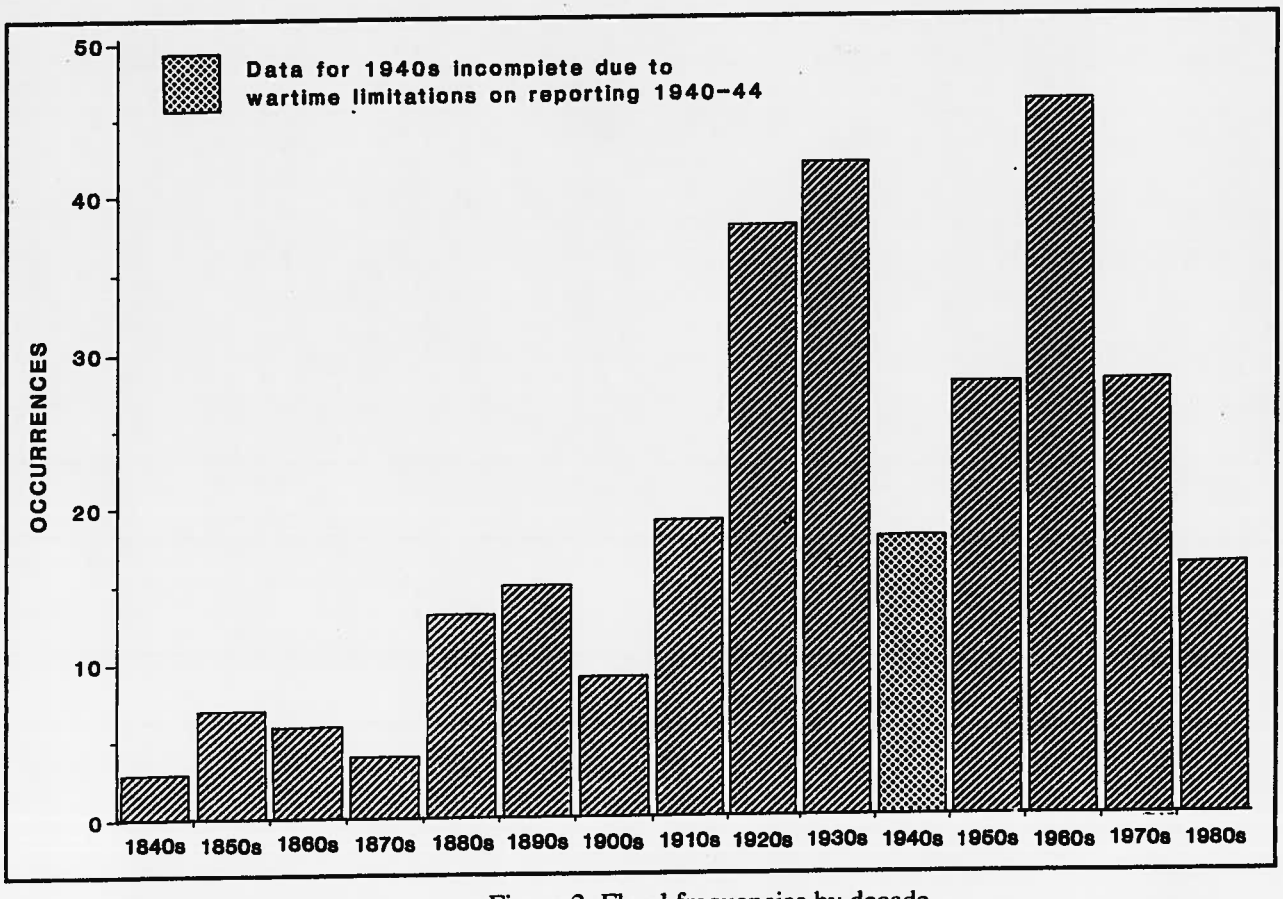


Figure 2: Flood frequencies by decade

1928 (10 floods), 1929 (9 floods) and 1935 (10 floods) highlight a phase of increased flood frequency and also mark a peak frequency which has not been matched since. The running means identify this peak together with another peak frequency between 1953 and 1966, a 14 year period with 60 flood events.

*Flood types*

Floods in Cork are caused mainly by a combination of rainfall and tides. This allows a logical classification of floods into five types based upon the relative importance of these conditions. A sixth type is also possible to accommodate floods caused by other factors. The types are as follows:

*Flood type 1*: Floods caused primarily by the state of the tide. These are normally either high tides or spring tides, usually containing a storm surge in addition to the water height of the river Lee.

*Flood type 2*: Floods which are 'tide-led', but with small contribution from rainfall as well.

*Flood type 3:* Floods which have their origin in bot tidal and rainfall conditions in more or less equa proportions.

*Flood type 4*: Floods due to rainfall predominantly, bu with some contribution from tidal conditions.

*Flood type 5*: Floods which occur when rainfall is th primary cause and when there is no contribution fron tidal conditions.

*Flood type 6*: Floods which are a response to condi tions not covered by the previous categories. Sudde temperature changes may cause snowmelt and icemel resulting in floods. Another flood situation occur when there are major releases from the Inniscarra dam usually arising when the dam is at capacity and there are substantial influxes of water from the catchment.

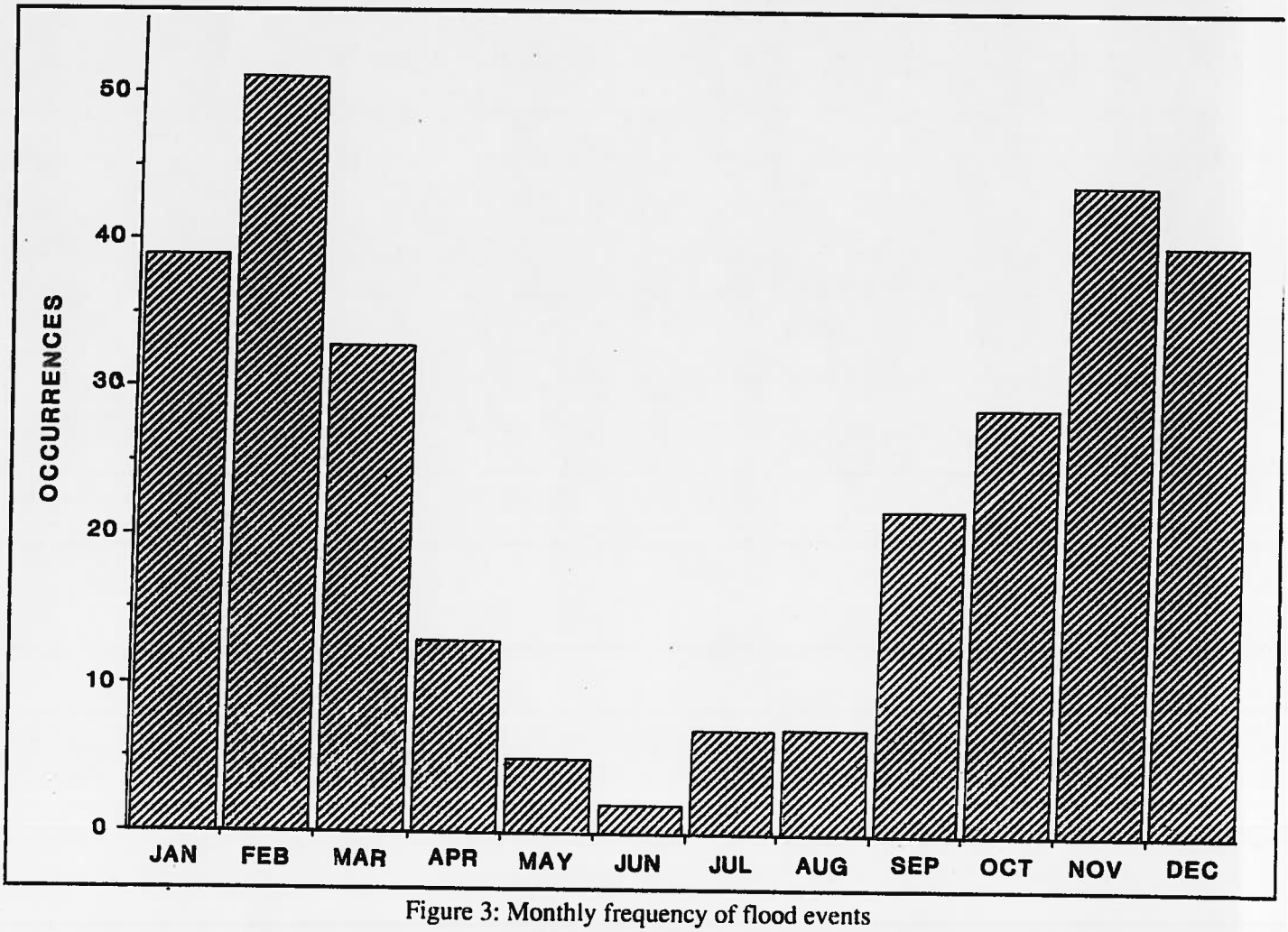


Figure 3: Monthly frequency of flood events

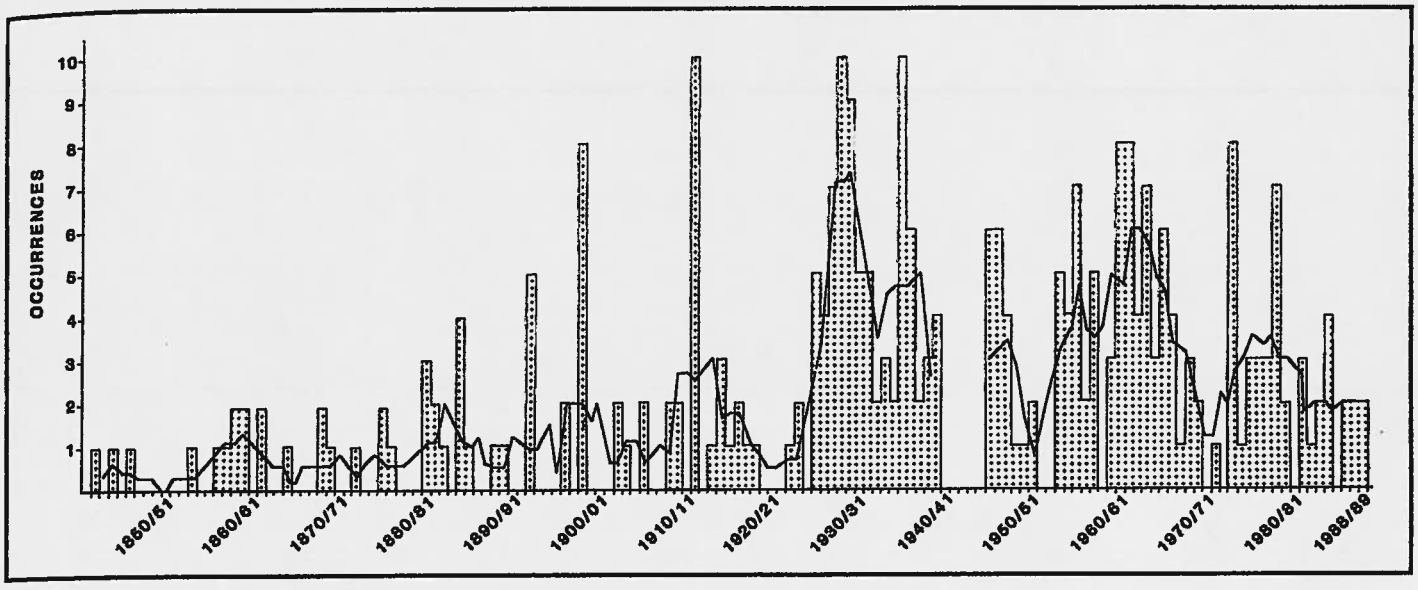


Figure 4: Annual flood frequencies and five year running means

The most frequent flood type was type 5, when rainfall was the predominant cause and tidal factors were minimal. 100 of the 292 floods (34.3%) belonged to this type. The next most common type was type 3, when a combination of rainfall and tidal conditions operated to cause flooding. On the other hand, the least common flood type was type 6. A breakdown by type and decade is given in Table 1.

Chronologically, there appears to be a change in the dominant flood type over the researched period. Type 5 floods, caused primarily by rainfall, are the dominant type for most of the first nine decades, except for the 1890s. Thereafter, there is a marked increase in the importance of tidal and other factors, although rainfall retains its role as the overall primary cause of flooding.

Using a scoring scheme for each flood based on the relative importance of rainfall, tides and other factors in the flood, as shown in Table 2, rainfall stands out as the primary cause of flooding in nearly all decades (Figure 5). The mean rainfall for the 48 hours preceding a flood event was 22mm over the period as a whole, but there is a noticeable decline in the decadal means for this value, from 34mm-23mm up to the first decade of the present century to 24mm-17mm thereafter.The lowering of this rainfall threshold is linked to an increase in the role of tidal conditions in the present century. Indeed, 'tide-led' floods briefly become dominant in the 1930s and 1950s.

Table 1: Flood type frequency by decade

| | Flood Types | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Total |
| 1840s | | | | | 2 | 1 | 3 |
| 1850s | | | | | 7 | | 7 |
| 1860s | 1 | | 2 | | 3 | | 6 |
| 1870s | | | 2 | | 2 | | 4 |
| 1880s | | | 3 | | 10 | | 13 |
| 1890s | 1 | 4 | 5 | 1 | 4 | | 15 |
| 1900s | 1 | | | 1 | 7 | | 9 |
| 1910s | 1 | 4 | 4 | | 10 | | 19 |
| 1920s | 3 | 1 | 9 | 7 | 17 | 1 | 38 |
| 1930s | 5 | 10 | 16 | 3 | 5 | 3 | 42 |
| 1940s | | 4 | 10 | 1 | 3 | | 18 |
| 1950s | 6 | 7 | 9 | 2 | 2 | 2 | 28 |
| 1960s | 4 | 8 | 16 | 5 | 12 | 1 | 46 |
| 1970s | | 7 | 5 | 5 | 8 | 3 | 28 |
| 1980s | | 2 | 2 | 3 | 8 | 1 | 16 |
| Total | 22 | 47 | 83 | 28 | 100 | 12 | 292 |

Table 2: Scores for flood types

| | Flood types | | | | | |
|---|---|---|---|---|---|---|
| Cause | 1 | 2 | 3 | 4 | 5 | 6 |
| Tides | 1.0 | 0.75 | 0.5 | 0.25 | 0 | 0-0.75 |
| Rainfall | 0 | 0.25 | 0.5 | 0.75 | 1.0 | 0-0.75 |
| Other | 0 | 0 | 0 | 0 | 0 | 0.25-1.0 |

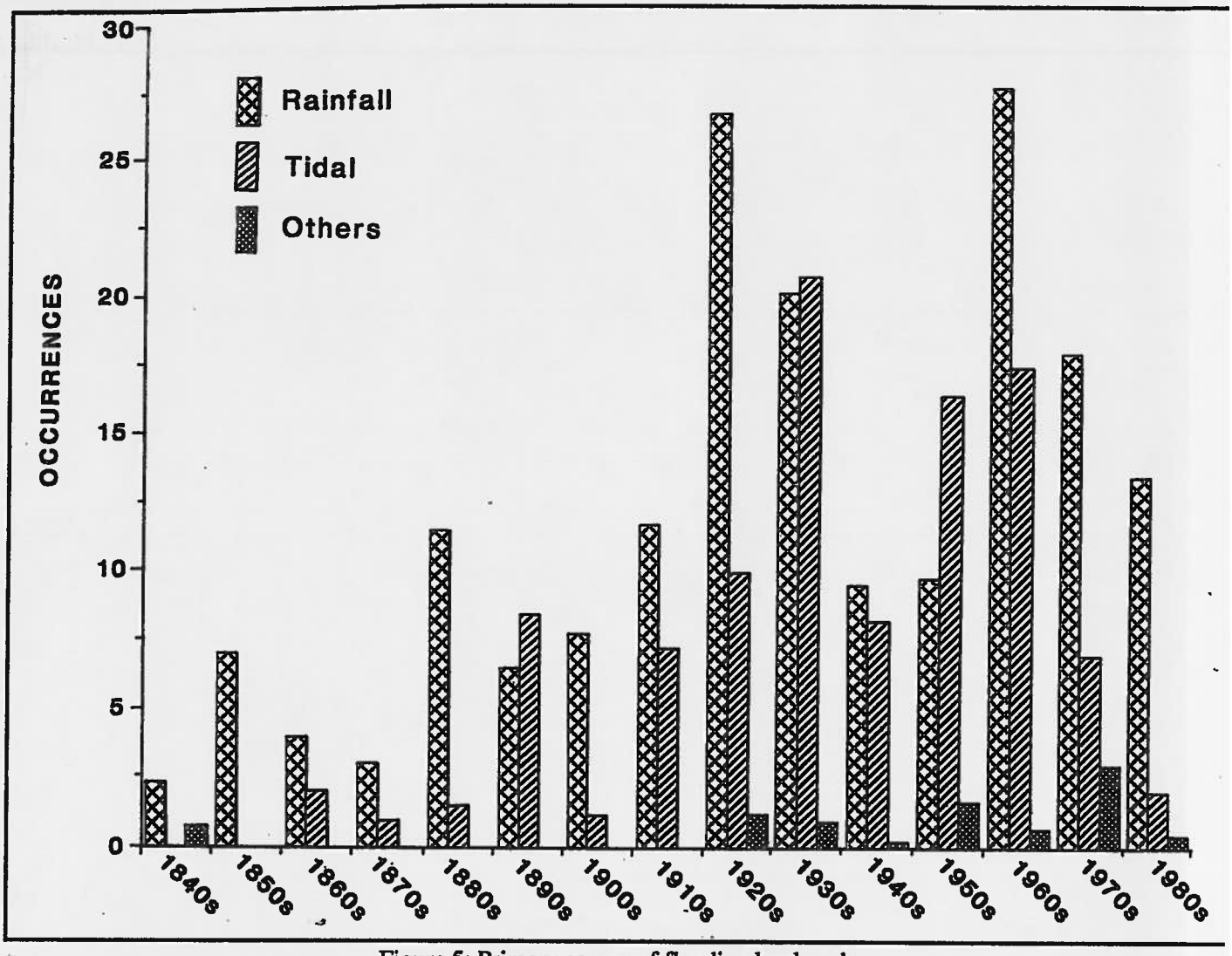


Figure 5: Primary causes of flooding by decade

**Patterns of atmospheric circulation**

Lamb circulation types (Lamb, 1972) were used to assess the influence of synoptic conditions on the flood events associated with rainfall. The relationship between flood types and and circulation types is summarised in Table 3, for 1861-1970. This analysis uses the seven primary circulations types and an unclassified group, while the hybrid types were grouped with their parent type. The dominance of southerly and cyclonic circulations is apparent for all the flood types, except for the unclassified group of floods. It should be noted that within the southerly circulation type is included the southeasterly and southerly hybrid types.

That this result is not simply a product of a higher frequency of cyclonic and southerly circulation days can be seen from the comparisons shown in Table 4 for the same period. A higher frequency of flood events occurred in association with southerly (and hybrids) and cyclonic (and hybrids) circulations than would be expected from the total frequencies of these circulation patterns for the period as a whole.

There is a strong link between circulation type and rainfall yield in Ireland (Sweeney, 1985). Atmospheric circulation types most frequently associated with flood events are also those which have the highest mean daily rainfall yields.

The Lamb circulation types generalise circulation patterns for a large area between latitude 50-60°N and 10°W-2°E. Within that area, significant variation of wind conditions may occur which may be of particular importance when considering extreme events. Wind data for Roches Point from 1876 show that 56% of the flood events had occurred when wind directions were within +/- 22.5° of the direction indicated by the Lamb circulation type for the larger area on that day. The local wind record was analysed, therefore, to see whether the finer detail provided by these data would give results consistent with the previous conclusions

Table 3: Flood type and patterns of atmospheric circulation, 1861-1970

| Circulation Type: | A | C | W | NW | N | S | E | U |
|---|---|---|---|---|---|---|---|---|
| Flood Type 1 | 4 | 8 | 4 | | | 3 | 2 | 1 |
| Flood Type 2 | 6 | 13 | 3 | | | 14 | 1 | |
| Flood Type 3 | 5 | 19 | 7 | | 1 | 36 | 4 | 6 |
| Flood Type 4 | | 1 | 2 | | 2 | 12 | | |
| Flood Type 5 | 5 | 27 | 15 | | | 24 | 5 | 2 |
| Flood Type 6 | 1 | | 2 | | | 2 | 2 | |
| All Types | 20 | 68 | 33 | 0 | 3 | 91 | 14 | 9 |

The most frequent wind direction at Roches Point associated with flood events in Cork city was the southeast (Table 5). But this was not as dominant as is often assumed. Of the 272 floods for which data was available, 59 (22%) were associated with SE winds. But winds from the SW were only slightly less frequent (43 occasions, or 16%). The popular perception of Cork floods occuring with SE winds is, therefore, an oversimplification of a more complex environment.

Tide-led' floods (types 1 and 2) have a higher association with SE wind directions than any other. Table 6 shows that 37.5% occured when winds were from the SE or SSE. The second dominant direction was from the SW or SSW (23.2%). In contrast, 'rain-led' floods (types 4 and 5) were associated most frequently with SW winds, but the percentage was down to 20%. Other directions, notably S,W and SE were only slightly less frequent. Clearly, these results reflect the range of wind directions possible when cyclonic circulations dominate the British Isles region and which are reflected in the high frequency of cyclonic days associated with flood events using the Lamb classification.

Table 4: A comparison of circulation type frequencies between flood days and all days, 1861-1970

| Circulation Type | Flood Days (%) | All Days (%) |
|---|---|---|
| W | 13.8 | 26.9 |
| NW | 0.0 | 4.9 |
| N + hybrid | 1.3 | 7.9 |
| E | 5.9 | 8.1 |
| S + hybrid | 38.1 | 9.0 |
| A + hybrids | 8.4 | 26.2 |
| C + hybrids | 28.5 | 17.0 |
| Unclassified | 3.8 | 0.0 |

## River and tidal conditions

Flooding in Cork city is frequently related to rainfall over the whole catchment rather than local rainfall alone. As rainfall becomes more significant as a flooding factor (flood types 3-5) so increasingly higher mean discharges at the Leemount Bridge are recorded. Only flood type 1 is associated with mean river discharges little different from the mean discharge for the entire period of the hydrographic record (Table 7).

Another hydrographic record is available for Horgan's Quay, close to the convergence of the river channels at the eastern end of the city island. As would be expected, this shows the tide heights of the flood days to be significantly higher for floods dominated by the tidal factor (Table 8). But with regard to tidal conditions, of special significance in Cork is the occurrence of storm surges and their association with atmospheric conditions.

A storm surge was calculated by the difference between the expected tidal height and the actual tidal height. This was possible for 137 floods of the 1930-1988 record. Wind data from Roches Point showed that the highest mean surges were associated with southeasterly and easterly winds, the southeast facing coast and the shape of the harbour enhancing this effect. These results are summarised in Table 8.

## Discussion and Conclusion

The Cork flood chronology shows an increase in the number of flood events during the present century. This is comparable with other available flood chronologies within the British Isles. In the context of longer term fluctuations this general pattern appears to be an increase after a low frequency of floods in the

Table 5: Flood frequency and wind direction by decade

| Decade: | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | | 1 | 1 | | | | | | 1 | | | 3 |
| NNE | 1 | | | 2 | | | | 3 | | | | 6 |
| NE | | | 4 | | 1 | | 1 | | | | | 6 |
| ENE | | | | | | | | | | 1 | | 1 |
| E | | | | | | 3 | | | 2 | 1 | 1 | 7 |
| ESE | 1 | | 1 | 1 | 1 | 1 | 1 | 4 | 6 | 3 | | 19 |
| SE | 1 | 2 | 2 | 7 | 4 | 12 | 2 | 5 | 11 | 7 | 6 | 59 |
| SSE | 2 | | 1 | 3 | 4 | 2 | 3 | 5 | 6 | 3 | 2 | 31 |
| S | 1 | 2 | | 2 | 5 | 4 | 1 | 4 | 6 | | 2 | 27 |
| SSW | 3 | 3 | | | | 4 | | | 4 | 5 | 1 | 20 |
| SW | 2 | 2 | | 3 | 9 | 11 | 5 | 3 | 4 | 2 | 2 | 43 |
| WSW | | 2 | | | | 2 | 1 | 1 | | 2 | 1 | 9 |
| W | 2 | 1 | 2 | 2 | 7 | 2 | 1 | 1 | 3 | 1 | | 22 |
| WNW | | | | 1 | 3 | 1 | 1 | 2 | | | | 8 |
| NW | | 2 | | | 1 | | 1 | | 1 | 1 | | 6 |
| NNW | 1 | 1 | | | | | | | 1 | | 1 | 3 |
| VAR | | | | | | | | 1 | | | | 1 |
| CALM | | | 1 | | | | 1 | | | 2 | | 4 |
| | | | | | | | | | | | Total | 272 |

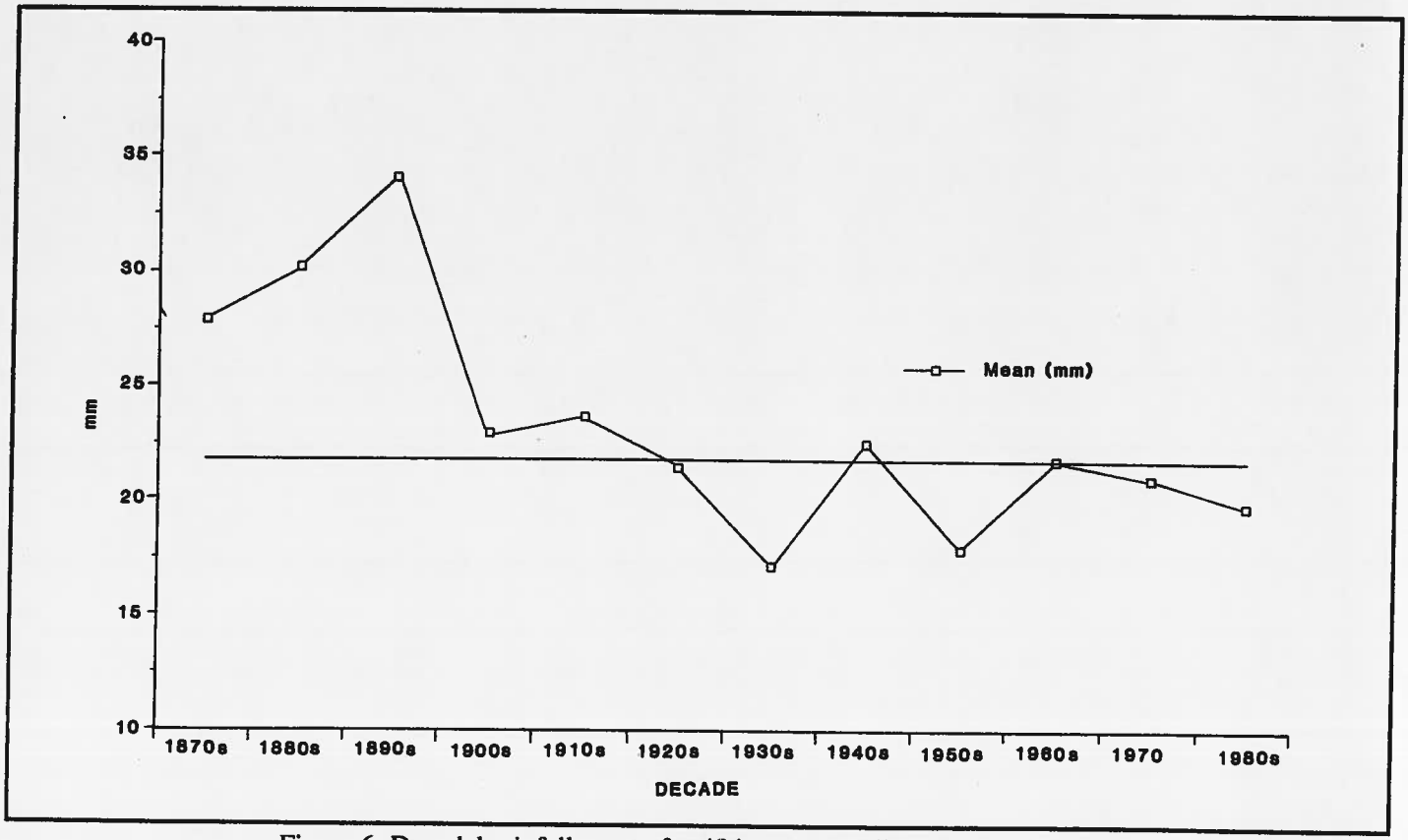


Figure 6: Decadal rainfall means for 48 hours preceding each flood event

Table 6: Flood type (1-5) and wind direction, 1876-1988

| Flood Type: | Type 1 & 2 (mainly tidal) | Type 3 (mixed) | Type 4 & 5 (mainly rain) |
|---|---|---|---|
| N | 2 | 1 | 2 |
| NNE | 2 | | 1 |
| NE | | | 3 |
| ENE | | | |
| E | 1 | 3 | 2 |
| ESE | | 7 | 9 |
| SE | 17 | 20 | 11 |
| SSE | 5 | 17 | 5 |
| S | 6 | 7 | 14 |
| SSW | 7 | 6 | 6 |
| SW | 10 | 11 | 18 |
| WSW | 1 | 3 | 2 |
| W | 2 | 5 | 13 |
| WNW | 5 | 2 | 1 |
| NW | 2 | 2 | 1 |
| NNW | 1 | | 1 |
| VAR | 1 | | 1 |
| CALM | 1 | 1 | 1 |

nineteenth century (Lamb, 1984). Other flood chronologies have shown that within the present century the decades of increased flood events have been the 1920s and 1930s followed by the 1950s and 1960s, particularly with regard to flood events of exceptional severity (Hickey, 1990). This characteristic also occurs in the Cork chronology which shows that the present frequency of flooding is less than the peak frequencies of 1925-1940 (approximately) and 1953-1966. But set against these similarities detailed comparisons between chronologies show that the Cork flood event frequency is not only higher, but differs significantly in timing.

The recognition of six flood types in Cork city, primarily on the basis of the relative significance of tidal and rainfall factors associated with each flood, reveals significant variations in the flood chronology. The flood type in which rainfall is the principal cause was the most frequent over the 148 years although the flood type in which the significance of both rainfall and tidal conditions were approximately of equal importance also had a high frequency. While the rainfall factor has been stronger than the tidal factor the latter has increased in relative importance during the present century, particularly during the 1930s-1960s. There was a clear dominance of cyclonic and southerly circulations over the British Isles region for most of the flood types. At a more local scale southeasterlies were most often associated with flood events, their contribution being particularly enhanced by producing the highest mean tidal surge of all wind directions. However, these winds are not as dominant in flood events as is often assumed. In particular, 'rain-led' floods are associated most frequently with southwesterly winds. At the same time the threshold value for rainfall over the 48 hours preceding a flood event has declined.

Variations between regions documented in other flood chronologies also demonstrate the importance of local rainfall, wind conditions and catchment details. The limited number of such studies and their diversity of detail preclude the recognition of widespread uniformities in flood event frequency patterns over the British Isles except at the most generalised level.

**Acknowledgements**

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Table 7: Mean discharge per flood by flood type, 1950-1988

| Flood type: | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Flood days | 9 | 20 | 27 | 14 | 27 | 7 |
| Mean discharge (cumsecs) | 39.0 | 66.0 | 93.2 | 147.3 | 109.2 | 152.1 |

Table 8: Mean tide height per flood by flood type, 1930-1988

| Flood type: | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Flood days | 15 | 35 | 56 | 16 | 32 | 11 |
| Mean tide height (m) | 5.01 | 5.01 | 4.98 | 4.76 | 4.33 | 4.84 |

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